Journal of the Nigerian Association of Mathematical Physics
***Volume* 25 (November, 2013), pp 215 – 220**

Assessment of Groundwater Quality in Five Communities in Esan North East LGA of Edo State, Nigeria.

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Abstract

Groundwater exploitation is generally considered as the only realistic option for meeting dispersed rural population water demand. Availability of potable groundwater has been a major problem in Uromi, Esan North East of Edo State. Evaluation of geophysical and chemical characteristics is essential for the development of groundwater resources in the area.

To study groundwater potential in the area, Schlumberger Electrode Configuration and the IP2WIN method of interpretation was adopted. The SAS300B ABEM Terrameter was utilised for the acquisition of data and the global positioning system (GPS) was used to map out various vertical electrical sounding stations in the area. Geochemically, 5 samples of groundwater were taken and subjected to physical and chemical analysis using WHO drinking water standard method. The results from the field and laboratory analysis revealed evidence of pollution from both physical and chemical sources. Five Vertical Electrical Sounding data were acquired in order to evaluate groundwater geophysically within the locations in Uromi. Expectantly, water bearing formations (aquifers) were found in some of the locations such as St. Theresa Catholic Church, Ukoni and Esan Model Boys Grammar School Ubierumum-Oke, with GPS Co-ordinates N06^0 43.019' E006^0 21.470' and N06^0 40.997' E006^0 17.354' at depths of 32.43 meters and 69.90 meters below the earth surface respectively. This study therefore reveals the following: that the selected hand dug wells in Uromi is not safe for consumption because of high nitrite which was above the permissible limits recommended by WHO for drinking water. It was further established that the wells were polluted in areas nearer to farm lands than areas further away from them.

***Keywords*:** Aquifer, Blue Baby Syndrome (BBS), Borehole, Hand dug well, Nitrite, WHO.

1.0 Introduction

Water is important to life, without it life cannot go on. Domenico, said it all when he stated that human life as with animals and plant life on the planet is dependent on water [1]. Water can therefore make or mar the economy and life style of a nation or a group of people because it is known to sustain life everywhere [2]. Without safe water near dwellings, the health and livelihood of families can be severely affected [3]. Groundwater exploitation is generally considered as the only realistic option for meeting dispersed rural water demand [4]. A large percentage of the world population depends on groundwater as their main source of drinking water [5 - 7]. This is because it is accessible anywhere, it is less capital intensive to develop and maintain, it is less susceptible to pollution and seasonal fluctuations and of natural good quality [8,9]. However, the quality is under intense stress from increasing demand and withdrawal, significant changes in land use pattern, climate change and pollution arising from geology and geochemistry of the environment [10,11]. Groundwater pollution has been a major water resource problem in area of Uromi. This is because a scientific understanding of the geophysical and geochemical aspects of groundwater pollution is essential for the development of the groundwater resource. This study aims at the assessment of groundwater quality which will aid the government authority in providing potable drinking water for the communities in Uromi. To the best of my knowledge, not much detailed study has been done in this area.

2.0 Study Area

The city of Uromi lies north-eastern Esan in Edo State, Nigeria, located on longitude 3° 24' E and latitude 6° 27' N. Almost the whole of the city is covered with land [12]. The people of Esan occupy a land mass covering about 54658.2

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metres [13]. The people of Uromi are known for farming. Its high and good farm output is greatly encouraged by the vegetation zone which is a rain forest zone, soil type (loamy). Among the Esan plateau dwellers, Uromi stands topmost on the plateau sitting at about 304.8 metres above sea level, [14] with the village of Ivue occupying the highest point on the Ishan plateau with about 454.15 metres above sea level [15].

3.0 Methodology

The equipment used in this study for the acquisition of data is the ABEM 300B Terameter and the schlumberger array in electrical resistivity survey was adopted. According to report from Ezomo [16] four terminals, the potential terminals P_1, P_2 and current terminals C_1 and C_2 were connected to the potential electrodes M, N and current electrodes A, B respectively of the ABEM SAS booster terrameter. The Terrameter was placed midway between the potential electrodes M, N using flexible cables provided [17]. A maximum spread of AB/2 equals 316.00meters was used. This reading was recorded immediately and the equipment switched off while the current electrode A,B separation was increased at intervals [18].

Conrad Schlumberger defined the resistivity (conductivity (δ) inverse) in terms of the electric field E rather than potential difference ΔV according to

$$J = \delta E \tag{1}$$

Where J is the current density, J and E are in the same direction in an isotropic medium because δ is a scalar quantity and current distribution is uniform in all directions.

General $J = \delta_{12}E$ if J and E are in opposite direction (2)

Equation (2) is valid generally in an anisotropic medium where the conductivity δ_{12} is a tensor of second rank. Isotropic medium satisfy Laplace's equation where the conductivity at a point on the earth's surface is independent of direction, hence

$$\nabla^2 V = 0 \text{ for } r >> 0 \tag{3}$$

Solution to equation (3) can be found for a particular earth's model by selecting the appropriate co-ordinate system to match the model geometry and using the appropriate initial or boundary conditions. In groundwater work, the solution is an approximation to the real earth because electrical resistivity theory and interpretation have been biased toward horizontal, homogeneous and isotropic earth model.

Variable separable techniques gave Conrad Schlumberger, the general solution for the potential of the surface of an n-layer earth having arbitrary resistivities and thicknesses as

$$V_{(r)} = \frac{\ell 1 I}{2\pi}\left[\frac{1}{r} + 2\int_0^\infty \theta_n(\lambda) j_0(\lambda_r)\, d\lambda\right] \tag{4}$$

Where J_0 is the Bessel function of zero order, first kind, θ_n is a function of the thickness and reflection coefficients for an assumed earth's model, also called Kernel function. Equation (4) can be differentiated and re-evaluated [19].

$$\ell_a(r) = r^2 \int_0^\infty T((\lambda) j(\lambda_r)\, d\lambda \tag{5}$$

Where T (λ) is the resistivity transform function. Equation (5) is therefore called convolution integral. Hence, it determines a linear digital filter (b_p) that converts resistivity transform samples to apparent resistivity values for theoretical earth's model as [20].

$$\ell_a(P) = \sum_p b_p T_{m-1} \tag{6}$$

The advantages of using theoretical method are: it is almost error free, its operation is simple and quick, depths or thicknesses can take any value and it is computerized.

The ETREX Legend H Model of the global positioning system (GPS) was used to map out various vertical electrical sounding (VES) stations in the 46 locations of Uromi. The resulting values of adjusted apparent resistivities were plotted (as ordinates) against current electrodes spacing AB/2 (as abscissa) using double logarithmic graphs for necessary qualitative and quantitative interpretations [21].

Groundwater samples were collected from hand dug well and were analysed in Edo Environmental Consults and Laboratory, Ministry of Environment and Public Utilities, Palm House Annex, Sapele Road, Benin City and the data obtained were compared with the World Health Organisation standards of potable drinking water [22]. The parameters evaluated were pH, TDS, Conductivity, TSS, Hardness, Turbidity, Colour, Alkalinity, Iron, (Fe), Zinc (Zn), Manganese (Mn), Copper (Cu), Nitrogen Oxide (NO_2^-) based on the procedures outlined by [23]. Their concentrations were established using standard laboratory procedures: pH meter, EC meter, TDS meter, Turbidity meter, Titrometric method, Atomic Absorption spectrophotometer, UV spectrophotometer.

4.0 Results and Discussion

The test parameters of physicochemical properties are shown in Table 1. The result of the geophysical survey employing the techniques of vertical electrical sounding (VES) are presented as field/computer iterated curves shown in Figures 1-5 and their corresponding subsurface lithological tables shown in Tables 2-6. The results of each location are presented below with a view of determining the presence of aquifer, soil lithology, total depth of penetration of current and evaluation of water quality. The test result of physicochemical properties of hand dug well collected from various communities in Uromi is shown in Table 1.

Computer iteration curves are shown in Figures 1-5 and the corresponding subsurface lithological tables are shown in Tables 2-6.

The sounding was done 100 meters away to St. Theresa Catholic Church, Ukoni, Uromi, with a GPS Co-ordinate of N06^0 43.019' E006^0 21.470'. The result of the geoelectric structure shows a five-layer KHKQ-type curve. Layers 1 – 5 have resistivity values of 1715 ohm-m, 4129 ohm-m, 1121 ohm-m, 15802 ohm-m and 3179 ohm-m respectively. Layer 1 has thickness of 0.5m and contains probably top soil. Layers 2 and 3 with thickness 4.67m and 9.06m respectively contain probably sand stone. Layer 4 of thickness 18.2m is dry sand while layer 5 contains probably small water bearing sand. The total depth of penetration is 32.43 meters. The depth of probable aquifer is 32 meters (Perched aquifer was encountered).

The physicochemical analysis of well water sample carried out in Ukoni, Uromi, shows that the parameters analysed for groundwater are within the WHO standards of potable drinking water except for NO_2^- (nitrite) 4.22mg/l which was above the WHO standards for drinking water of 3.0mg/l. It was observed that the well was cited close to a pineapple farm. Information from residents confirmed the use of Nitrogen-Phosphorous Potassium (NPK) fertilizer and other times animal manure. The use of this fertilizer can have a direct impact on the quality of groundwater.

The survey was done 50 meters to Awo Primary Health Care Centre, Awo, Uromi, with a GPS Co-ordinate of N06^0 43.823' E006^0 22.182'. The result shows an AA-type curve having three-layer. Layers 1, 2 and 3 have resistivity values of 7.38 ohm-m, 6.11 ohm-m and 4890 ohm-m respectively. Layers 1 and 2 have thickness 5.10m and 9.66m which is composed of probably top soil and clay respectively. Layer 3 contains probably sand stone. The maximum depth of penetration is 14.76 meters. Water was not struck in this station.

The physicochemical analysis of well water sample carried out in Awo, Uromi, shows that the parameters analysed for groundwater are within the WHO standards of drinking water.

The sounding was recorded about 500 meters to Uwalor-Oke Primary Health Care Centre, Uwalor-Oke, Uromi, with a GPS Co-ordinate of N06^0 41.286' E006^0 19.399'. The result shows a three-layer AA-type curve. The first to third layer has resistivities 777 ohm-m, 5238 ohm-m and 7443 ohm-m respectively. The first two layers of thickness 1.09m and 48.9m contain probably top soil and sand stone respectively. The last layer is probably sand. The maximum depth is 49.99 meters. Water was not encountered here.

The physicochemical analysis of well water sample carried out in Uwalor-Oke, Uromi, shows that the parameters analysed for the groundwater collected were within the desirable limits of the WHO standards of drinking water except for NO_2^- (nitrite) 4.40mg/L which was above the WHO drinking water standards of 3.0mg/L. It was observed that the location where the hand dug well water samples were collected were close to farmlands in which nitrogen based fertilizers were used due to intense farming in the area, thereby leading to high nitrite concentration in groundwater.

The survey was done in the premises of Esan Boys Model Grammar School, Ubierumum-Oke, Uromi, with a GPS Co-ordinate, of N06^0 40.997' E006^0 17.354'. The result shows a four-layer KQH-type curve. Layers 1 – 3 have resistivity values of 3916 ohm-m, 11143 ohm-m, 885 ohm-m with their corresponding thickness of 10.9m, 23.1m and 36m respectively. The fourth layer has resistivity 79.2 ohm-m. Layers 1 – 4 have the soil lithology of probably top soil, sand stone, sandy clay and water bearing sand respectively. The maximum depth of penetration is 69.9 meters. Perched aquifer was present in this location at the depth of 69.9 meters.

The physicochemical analysis of well water sample carried out in Obierumum-Oke, Uromi shows that all the parameters analysed were within the World Health Organisation standards of drinking water except for NO_2^- (nitrite) 3.86mg/L which is above the WHO standards of drinking water of 3.0mg/L. It was observed that the location where the well water samples were collected were close to farmlands (maize and melon) in which nitrogen based fertilizers were used due to intense farming in the area, thereby leading to high nitrite concentration in groundwater.

The sounding was done beside St. Patrick's Catholic Church, Ewoyi, Uromi, with a GPS Co-ordinate of N06^0 41.461' E006^0 18.203'. The result of the geoelectric section shows a four-layer AA-type curve. Layers 1 – 4 have resistivity values of 76.4 ohm-m, 235 ohm-m, 843 ohm-m and 99023 ohm-m respectively. Layer 1 have thickness of 0.5m and contain probably top soil. Layers 2 and 3 with thickness 2.45m and 8.46m respectively contain probably clay and sand stone respectively the last layer is probably dry sand. The total depth of penetration is 11.41 meters. No evidence of aquifer in this station.

The physiochemical analysis of well water sample carried out in Ewoyi, Uromi, shows that the parameters analysed for groundwater are within the WHO drinking water standards except for pH (5.86) and NO_2 (3.10mg/l) respectively which is above the safe limits of the WHO drinking water standards pH (6.5-8.6) and NO_2 (3.0mg/l) respectively. It was observed that the location where the hand dug well samples were collected were close to farmland (cassava) in which nitrogen based fertilizers were used due to intense farming in the area, leading to high nitrite concentration in groundwater. Nitrite in drinking water can be hazardous to health especially for infants (blue baby syndrome). Symptoms include shortness of breath and blueness of the skin.

Conclusion

This paper has provided information on the depth to groundwater, thickness of the aquifer and the evaluation of groundwater quality in the study area. This information will aid the government in the provision of potable drinking water for the people of Uromi. The study area as can be seen from the data acquired and interpreted in this survey is on a higher level (i.e higher elevation). It is observed that elevation plays a major role in the determination of water level in an area. The result obtained therefore, using the Schlumberger resistivity electrode array showed that Ukoni and Ubierumun-oke with maximum penetration of 32.0 meters and 69.9 meters respectively had the presence of a perched aquifer, while aquifer was not encountered in Awo, Uwalor-oke and Ewoyi. However, the survey areas may hold good prospects for groundwater when very long current electrode spacing is used thus going through a great depth to reach the water table. It was also observed that the groundwater sampled in Awo was within the safe limits of the World Health Organisation drinking water standards as at time of assessment, Ukoni, Uwalor-oke and Ubierumum-oke had high nitrite concentrations of (4.22mg/l), (4.44mg/l) and (3.86mg/l) respectively which was above the World Health Organisation standards of 0.3mg/L, while Ewoyi had low pH and high nitrite concentration of (5.85) and (3.10mg/l) respectively which were not within the ecological benchmark of the World Health Organisation drinking water standards. The high value of nitrite concentration is due to the use of Nitrogen based fertilizers as a result of intense farming. In conclusion, the presence of nitrite in water can result to acidic water and making it unsafe for consumption. Therefore in order to improve the quality of groundwater in the study area, boreholes/hand dug wells should not be cited along the flow path of potential pollution sources such as farm lands were nitrogen based fertilizers are used, provision of water treatment plant should be provided for the people in the study area and also the hand dug wells should undergo pH correction by addition of sodium bicarbonate as a purifier for acidic groundwater, this will help to mitigate the high concentration of nitrite and pH, thereby bringing the values to fall within the acceptable World Health Organisation drinking water standards. The information on the assessment of groundwater in the study area will also aid government authority in abating water pollution problem in the area.

Table 1: Result of Physicochemical Properties.

Hand dug well No.	Ph	(EC) ($\mu s/cm$)	TDS (Mg/l)	TSS (Mg/l)	Hardness (Mg/l $CaCO_3$)	Turbidity (FAU)	Colour (ptCo)	Alkalinity (Mg/l $CaCO_3$)	(Fe) (Mg/l)	Zn (Mg/l)	Mn (Mg/l)	Cu (Mg/l)	NO_2^- (Mg/l)
Ukoni	6.62	33.9	23.5	Nil	1.48	1	1	47	BDL	0.22	BDL	BDL	**4.22**
Awo	6.81	21.1	14.9	Nil	1.39	0	2	42	BDL	0.03	BDL	BDL	Nil
Uwalor-oke	6.93	214	149	Nil	2.88	0	2	100	BDL	0.11	BDL	BDL	**4.40**
Ubierumun-oke	6.57	18.8	14.4	Nil	2.53	3	1	120	BDL	0.21	BDL	BDL	**3.86**
Ewoyi	**5.86**	36.7	18.2	Nil	4.60	0	1	156	BDL	0.23	BDL	BDL	**3.10**
WHO standards	**6.5-8.5**	**1000**	**1000**	**N/A**	**100-500**	**5**	**15**	**500**	**3**	**5**	**0.5**	**1.00**	**3.00**

FAU = Formazin Attenuation Units, $\mu s/cm$ = Micro second per centimetre, **Mg/l** = Milligram per litre, **ptCO** = Platinum-Cobalt Scale BDL = Below Detectable limit

Table 2: VES for St. Theresa Catholic Church, Ukoni

Layer	Apparent Resistivity ℓa (ohm-m)	Thickness h (m)	Soil Lithology
1	1715	0.5	Top soil
2	4129	4.67	Sand stone
3	1121	9.06	Sand stone
4	15802	18.2	Dry sand
5	3179		Small water bearing sand

Total Depth = 32.43 metres

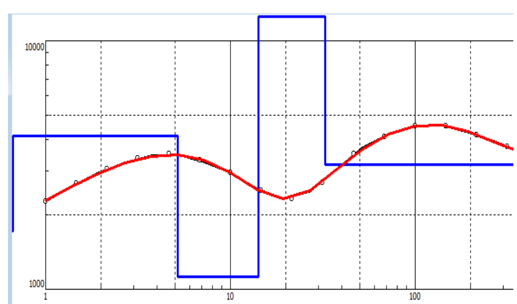

Fig 1: VES Curves for St. Theresa Catholic, Ukoni

Table 3: VES for Awo Primary Health care

Layer	Apparent Resistivity ℓa (ohm-m)	Thickness h (m)	Soil Lithology
1	7.38	5.10	Top soil
2	6.11	9.66	Clay
3	4890	9.06	Sand stone

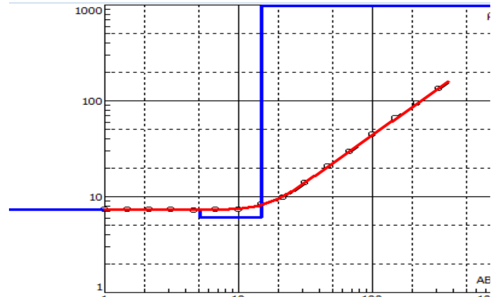

Fig 2: VES Curves for Awo Primary Health Care Centre

Total Depth = 14.76 metres

Table 4: VES for Uwalor-oke Primary Health care

Layer	Apparent Resistivity ℓa (ohm-m)	Thickness h (m)	Soil Lithology
1	777	1.09	Top soil
2	5238	48.9	Sand stone
3	7443	9.06	Sand

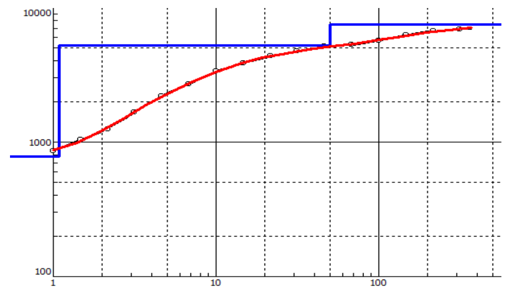

Fig 3: VES Curves for Uwalor-oke Primary Health care Centre

Total Depth = 49.99 metres

Table 5: VES for Esan Model Boys Grammar school

Layer	Apparent Resistivity ℓa (ohm-m)	Thickness h (m)	Soil Lithology
1	3916	10.9	Top soil
2	11143	23.1	Sand stone
3	885	36	Sandy clay
4	79.2		Small water bearing sand

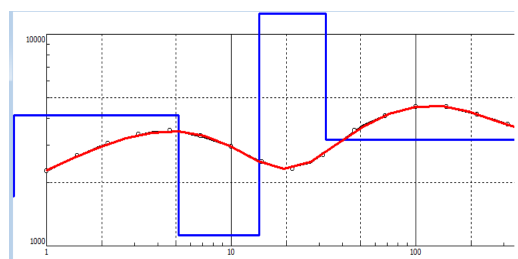

Fig 4: VES Curves for Esan Boys model Grammar School

Total Depth = 69.9 metres

Table 6: VES for St. Patricks Catholic Church, Ewoyi,

Layer	Apparent Resistivity ℓa (ohm-m)	Thickness h (m)	Soil Lithology
1	76.4	0.5	Top soil
2	235	2.45	Clay
3	843	8.46	Sand stone
4	99023	∞	Dry sand

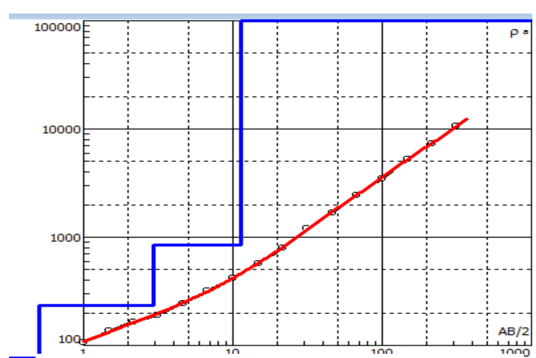

Fig 5: VES Curves for St. Patricks Catholic Church, Ewoyi

Total Depth = 11.41 metres

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